Design of RCC box (1x2.0x2.0)

Dimensions of Box

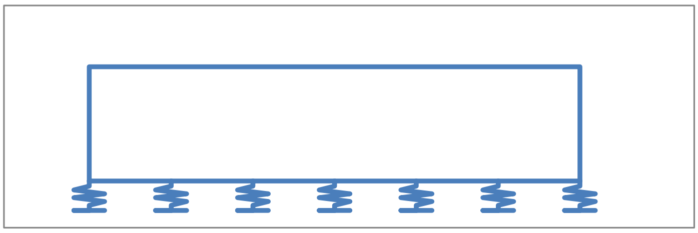
No. of Cell	=	**1**	Clear Width of cell	=	**2.00 m**
Top Slab Thickness	=	**0.200 m**	Clear Height of Cell	=	**2.00 m**
Bot. Slab Thickness	=	**0.225 m**	C/C Width of structure	=	2.23 m
Side Wall Thickness	=	**0.225 m**	C/C Height of structure	=	2.21 m
Wearing Coat	=	**65mm**	Total Width of Structure	=	2.45 m
Haunch size	=	**150 mm x 150 mm**	Total Height of Structure	=	2.43 m
			Railing/CB width	=	**0.50 m**

Basic Parameters

Coefficient of Earth Pressure	=	**0.5**
Density of fill	=	2.00 t/m^3
Density of Concrete	=	2.50 t/m^3
Live Load Surcharge	=	1.20 m
Safe Bearing Pressure	=	**10** t/m^2
Modulus of Subgrade Reaction	=	**1000** $t/m^2/m$

Idealised Structure for Staad Analysis

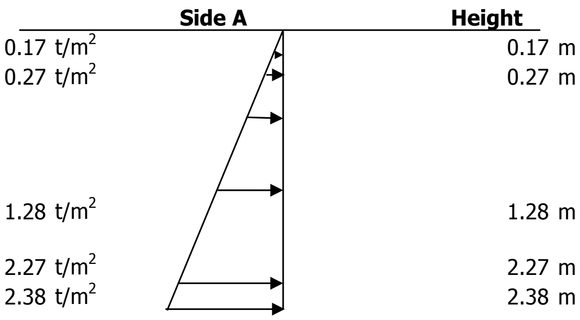
Idealisation has been done at centreline of structure for 1m strip



Spacing between End Springs	=	0.11 m
Spacing between Intermediate Springs	=	0.33 m
Spring Constant at End Support	=	56.3 t/m
Spring Constant at Penultimate Support	=	194.8 t/m
Spring Constant at Intermediate Support	=	333.3 t/m

Load Calculation

1) Earth Pressure



2) Live Load Surcharge

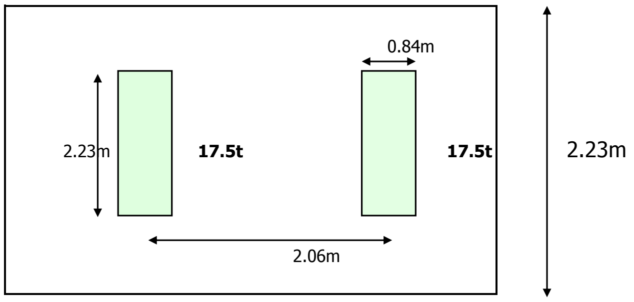
Live Load Surcharge = 1.200 t/m

3) Check for Base Pressure

Weight of Top Slab	=	1.23 t/m	
Weight of Bottom Slab	=	1.38 t/m	
Weight of Side wall	=	2.25 t/m	
Weight of Intermediate side wall	=	0.00 t/m	
Weight of Railing/Crash Barrier	=	2.45 t/m	
Weight of wearing coat	=	0.25 t/m	
Base Pressure Without Live Load	**=**	3.08 t/m^2	**OK**
Base Pressure With Live Load	=	4.10 t/m^2	**OK**

4) Live Load

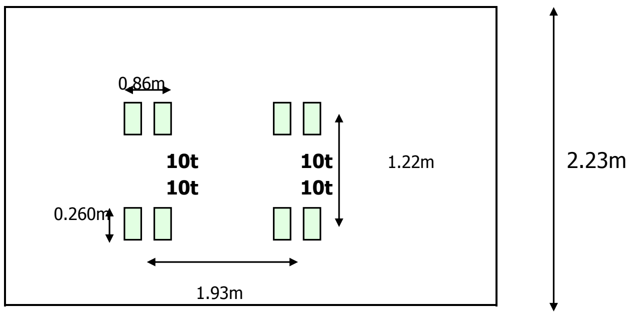
A) 70R Track at Mid Span



Total Load = **35t**

a (m)	b1 (m)	b/lo	α	beff (m)	Overlap	Effective Width (m)	Width along Span (m)	Load Intensity (t/m^2)	After Impact (t/m^2)
1.11	0.97	7.19	2.60	2.42	Yes	2.42	5.10	2.84	3.55

B) 40T Boggie Load at Mid Span



Total Load = **40t**

a (m)	b1 (m)	b/lo	α	beff (m)	Overlap	Effective Width (m)	Width along Span (m)	Load Intensity (t/m^2)	After Impact (t/m^2)
0.50	0.99	7.19	2.60	2.00	Yes	3.93	0.79	6.42	8.02

C) 70R Wheel (CG of Train at Centre of Structure)

S.No.	Load	a	α	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	17	**1.12**	2.60	2.44m	Yes	4.37	3.9t/m	**4.9t/m**
2	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
3	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
4	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
5	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
6	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
7	0	**0.00**	2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**

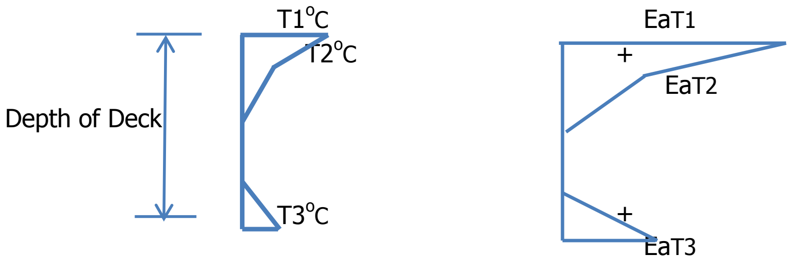
D) 70R Wheel (1st 17T on right wall)

S.No.	Load	a	α	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	17	**0.00**	2.60	0.99m	No	1.00	8.5t/m	**10.6t/m**
2	17	**0.86**	2.60	2.36m	Yes	4.29	4.0t/m	**5.0t/m**
3	0		2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
4	0		2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
5	0		2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
6	0		2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**
7	0		2.60	0.00m	No	1.00	0.0t/m	**0.0t/m**

* Effective width shall not be less than 1 otherwise intensity of load will be more than point load itself.

Temperature Gradient Case

Consider Temperature Rise Case/Positive Temperature Gradient



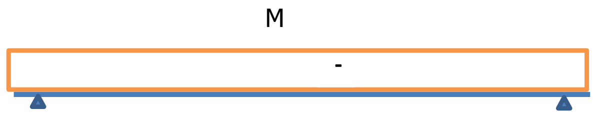
Temperature Gradient Locked in Stress Diagram

The above locked in stress will generate axial force & Bending Moment which is discussed below for different structure.

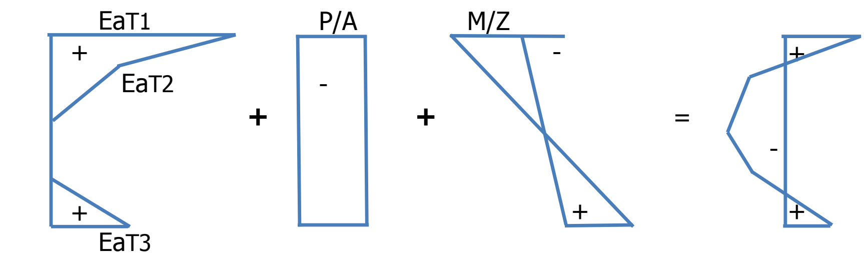
Effect of Temperature Rise Case on Simply Supported Span

Loading in Simply Supported Structure

BM in Simply Supported Structure



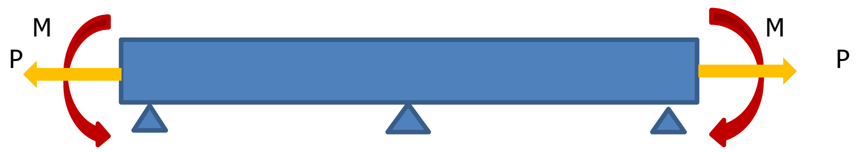
Stress Shall be Calculated by following Procedure



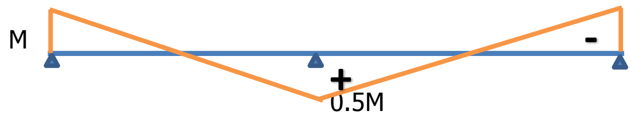
Stress Diagram Axial Tension Bending Moment Final Stress

Effect of Temperature Rise Case on Continuous Span

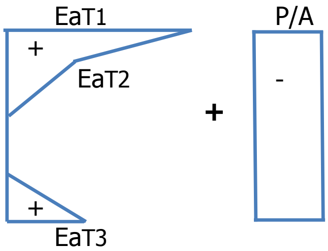
Loading in Continuous Span



BM in Continuous Span



Stress Shall be Calculated by following Procedure



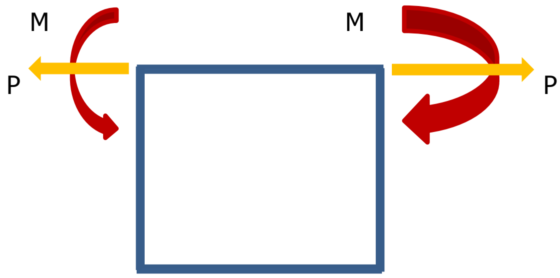
+ + M**/Z = Final Stress

Stress Diagram | Axial Tension | Bending Moment | Final Stress

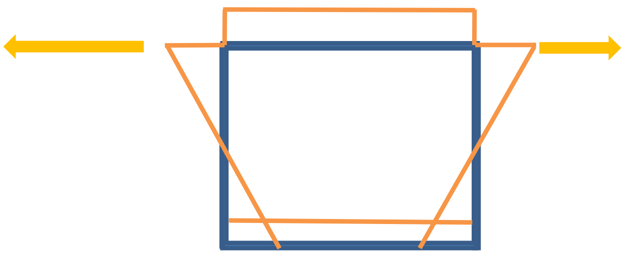
**BM shall be hogging near end support and sagging near Intermediate support

Effect of Temperature Rise Case on Box/Frame

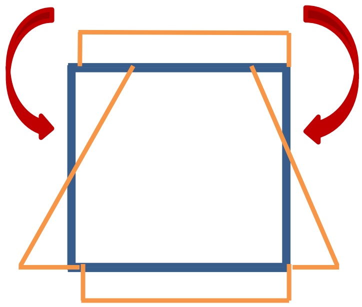
Loading in Box Frame



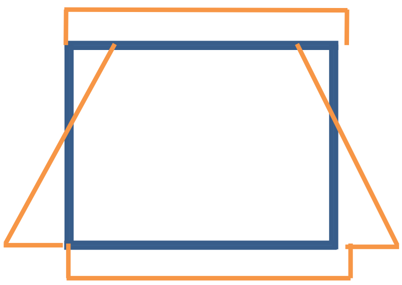
BM in Box Frame



BM due to Load

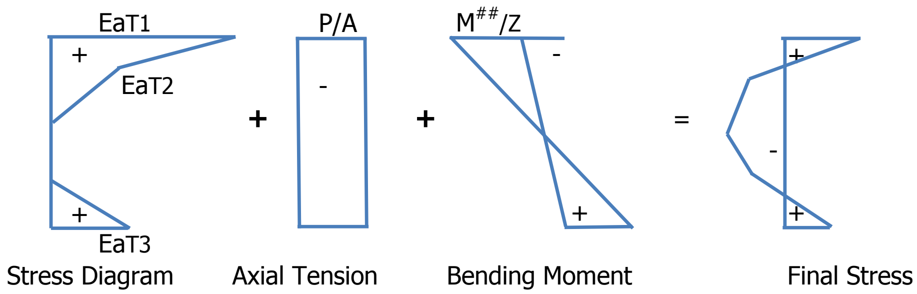


BM due to Moment



Final BM due to Load & Moment

Stress in top slab Shall be Calculated by following Procedure



##BM shall be hogging for top slab

CHECK FOR TEMPERATURE EFFECT; As per IRC - 6:-

Effect of temperature gradient

F = $E_c \alpha t A$

Ec = Modulus of Elasticity of concrete = 2.74E+06 t/m^2

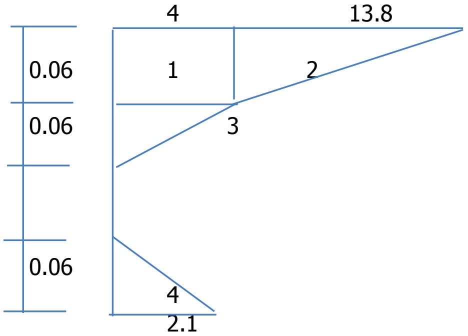
α = Co-efficient of thermal expansion = 1.20E-05

t = Temperature differential =

A = Sectional area of section where temperature differential is t

Average thickness of deck slab = 0.2

Effect of temperature Rise :

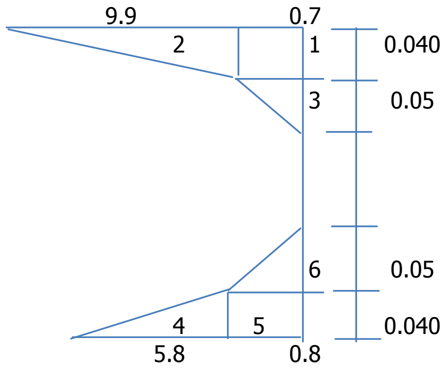


Sr No.	t	Factor	b	d	A=bxd	Force	Acting at	Ecc.
1	4.00	1.0	1.0	0.06	0.060	7.89	0.030	0.07
2	13.80	0.5	1.0	0.06	0.030	13.61	0.020	0.080
3	4.00	0.5	1.0	0.06	0.030	3.94	0.080	0.020
4	2.1	0.5	1.0	0.06	0.030	2.070	0.020	-0.080
					Sum=F	**27.507**	**Sum=F*e**	**1.55**

e* = Eccentricity of force from the centroidal axis of force

M = F*e = $E_c \alpha t/2Ae$

Effect of Temperature Fall :-



Sr No.	t	Factor	b	d	A=bxd	Force	Acting at	Ecc.
1	0.70	1.0	1.0	0.040	0.040	0.92	0.020	0.080
2	9.90	0.5	1.0	0.040	0.020	6.51	0.013	0.087
3	0.70	0.5	1.0	0.05	0.025	0.58	0.057	0.043
4	5.80	0.5	1.0	0.040	0.020	3.81	0.013	-0.087
5	0.80	1.0	1.0	0.040	0.040	1.05	0.020	-0.080
6	0.80	0.5	1.0	0.05	0.025	0.66	0.057	-0.043
					Sum=F	**13.523**	**Sum=F*e**	**0.219**

Effect of Uniform Temperature:-

(As per Clause - 218.2,IRC-6)

Maximum temperature of Kolkata region = 47.5 degree
Minimum temperature of Kolkata region = 0.00 degree

Difference between Maximum & Minimum Air temperature = 47.5 degree

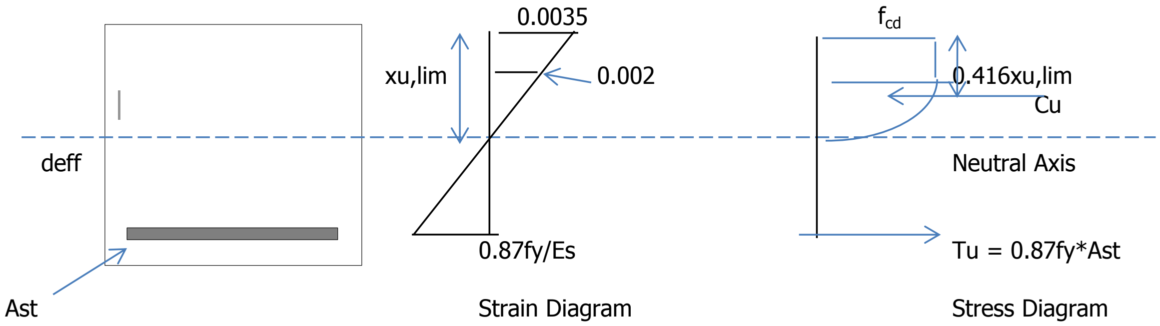
So,the bridge temperature at the time of constraint Max = 33.8 degree

So,the bridge temperature at the time of constraint Min = 13.8 degree

Therefore theLoad effect due to Temperature Fall = (+/-) 27.5 degree
say 30.0 degree

While applying it to STAAD file, as E values are to be taken half for long time effect, temp. is reduced to half while keeping E value as full. i.e 15 degree.
Shrinkage strain = 0.0002

MOMENT OF RESISTANCE OF RECTANGULAR CONCRETE SECTION
As per IRC:112-2011



ULTIMATE LIMIT STATE

Grade of Concrete f_{ck} = 30 N/mm^2

As per clause 6.4.2.8, IRC:112-2011

f_{cd} = $\dfrac{\alpha * f_{ck}}{\gamma_m}$ = 13.40

α = 0.67

Grade of steel f_Y = 500 N/mm^2

f_{Yd} = 434.8 N/mm^2

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = 0.87fy/Es

Es = 2.0E+05 MPa

Cu = fcd*b*(3/7xu,lim + 2/3*4/7xu,lim)

= 17/21*fcd*b*xu

= 0.8095*fcd*b*xu

cg of compression block from top = 0.416xu

Tu = (fy/1.15)*Ast

R_{lim} = $M_{u,Lim}/bd^2$ = 0.8095fcd*(xu/d)*(1-0.416*xu/d)

xu,li $\frac{p_t}{100} = \frac{A_{st}}{bd} = 0.973\frac{f_{cd}}{f_{yd}}\left[1-\sqrt{1-2.055\frac{R}{f_{cd}}}\right]$

R_{lim} = $M_{u,Lim}/bd^2$ = 4.97

It is $p_{t,\lim} = 97.3\frac{f_{cd}}{f_{yd}}\left[1-\sqrt{1-2.055\frac{R_{\lim}}{f_{cd}}}\right]$ astic branch is used

ıuse 8.2.1 (f), IRC:112-2011

Calculation of Reinforcement

Tensile reinforcement can be calculated from the following formula

where, $R = M_u/bd^2$

Limiting percentage of steel reinforcement for balanced section

where, $R_{lim} = M_{u,Lim}/bd^2$

Summary Of Moments (Basic combination)

Case	Member	Section	Node	Design Factored BM (t-m)	Remark
Basic combination	Top slab	Wall face	**14**	3.0	**Top face**
		Mid Span	**15**	4.5	**Bottom face**
	Bot. slab	Wall face	**2**	3.8	**Top face**
		Mid Span	**5**	6.0	**Bottom Face**
	Side wall	Tob slab face	**12**	4.1	**Earth face**
		Mid Span	**11**	1.9	**Earth face**
			11	0.7	**Inner face**
		Tob slab face	**10**	4.3	**Earth face**

Grade of Concrete	=	**M30**
Grade of Steel	=	**Fe500**
f_{cd}	=	1366 t/m^2
f_{Yd}	=	44343 t/m^2
Rlim	=	4.97

Summary of Reinforcement

Minimum required reinforcement

Section Mark as	Depth Provided	Min. Reinf. Reqd. on tension face	Min. Reinf. Reqd. on Comp.face
	m	cm^2/m	cm^2/m
14	0.20	2.4	1.2
15	0.20	2.4	1.2
2	0.23	2.7	1.35
5	0.23	2.7	1.35
12,11,10	0.23	2.7	1.35

Nodes	Design Bending Moment	Ru = Mu/(bd^2)	Effective Depth Required	Effective Depth Provided	Reinforcement Required (Subject to min.)	Reinforcement Provided					Check
	t-m		m	m	cm^2/m	Bar Dia (mm)	Spacing (mm)	Bar Dia (mm)	Spacing (mm	cm^2/m	
14	3.0	1.763	0.08	0.130	5.17	10	180	10	180	**8.73**	**OK**
15	4.5	2.271	0.09	0.140	7.17	10	180	10	180	**8.73**	**OK**
2	3.8	1.578	0.09	0.16	5.52	10	180	10	180	**8.73**	**OK**
5	6.0	2.567	0.11	0.15	8.86	10	180	12	180	**10.65**	**OK**
12	4.1	2.427	0.09	0.13	7.12	10	180	10	180	**8.73**	**OK**
11	1.9	1.142	0.06	0.13	3.35	10	180	10	180	**8.73**	**OK**
11	0.7	0.413	0.04	0.13	1.21	10	180	0	180	**4.36**	**OK**
10	4.3	2.548	0.09	0.13	7.48	10	180	10	180	**8.73**	**OK**

Distribution Reinforcement

Transverse steel as per Cl 16.6.1.1.(3) IRC 112:-2011
at least 20% of tension steel

S.No.	Surface	Reinf. Reqd/ cm^2/m	Reinf. Provided			Status
			Dia	Spacing	cm^2/m	
1. Top Slab	Top	1.4	10	225	**3.49**	**OK**
	Bottom	1.4	10	225	**3.49**	**OK**
2. Bottom Sl	Top	1.8	10	225	**3.49**	**OK**
	Bottom	1.8	10	225	**3.49**	**OK**
3. Side wall	Earth	1.5	10	225	**3.49**	**OK**
	Inner	1.5	10	200	**3.93**	**OK**

Design for SLS Rare Combinations

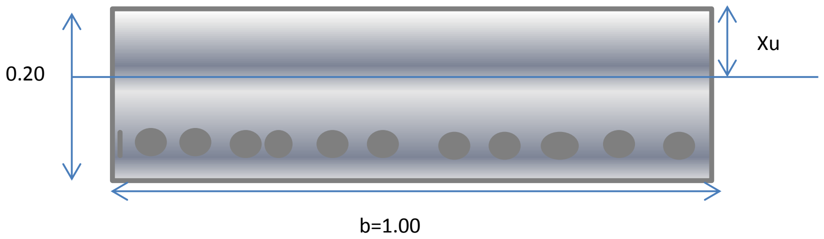
Grade of Concrete	=	**M30**
Grade of Steel	=	**Fe500**
f_{cd}	=	1366 t/m^2
f_{Yd}	=	40000 t/m^2

Summary Of Moments for SLS case(Rare combination)

Case	Element	Location	Node	Design BM (t-m)	
Normal	Top slab	Wall face	**14**	2.1	Hogging moment
		Mid Span	**15**	3.0	Sagging moment
	Bot. slab	Wall face	**2**	2.8	Sagging moment
		Mid Span	**5**	3.5	Hogging moment
	Side wall	Slab Face at top	**12**	2.9	Hogging moment
		Mid Span	**11**	1.3	Hogging moment
			11	0.0	Sagging moment
		Slab face at bottom	**10**	3.1	Hogging moment
Temp. Linear	Top slab	Wall face	**14**	2.0	Hogging moment
		Mid Span	**15**	2.7	Sagging moment
	Bot. slab	Wall face	**2**	2.6	Sagging moment
		Mid Span	**5**	3.2	Hogging moment
	Side wall	Slab Face at top	**12**	2.6	Hogging moment
		Mid Span	**11**	1.2	Hogging moment
			11	0.0	Sagging moment
		Slab face at bottom	**10**	2.8	Hogging moment
Temp. Linear+ Gradient	Top slab	Wall face	**14**	1.6	Hogging moment
		Mid Span	**15**	1.7	Sagging moment
	Bot. slab	Wall face	**2**	1.6	Sagging moment
		Mid Span	**5**	0.5	Hogging moment
	Side wall	Slab Face at top	**12**	0.6	Hogging moment
		Mid Span	**11**	0.6	Hogging moment
			11	0.0	Sagging moment
		Slab face at bottom	**10**	1.8	Hogging moment

Check for stress in concrete and steel

Calculation of Xu, Section Modulus for Top Slab



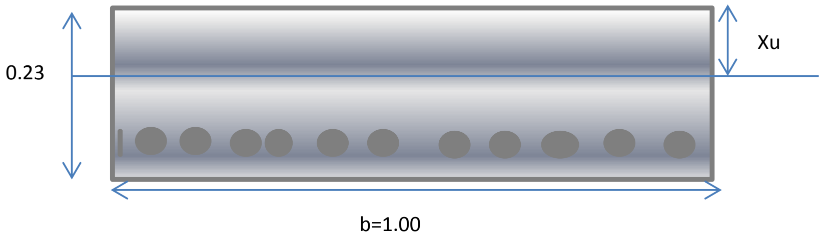
effective depth of section	0.1300	
Assume neutral axis	0.0484	
Modulur ratio	6.4516	

Comparing moment of area(for Compression and tension) about neutral axis

B*Xu*xu/2= m*ast*(d-Xu)

Moment of area above neutral axis		0.0012	
Moment area below neutral axis		0.0004594	
	Goal seek		0.000712
Crack moment of inertia of concrete		0.001181	m^4
Moment of inertia of steel		0.000022	m^4
Total crack moment of inertia		0.0012031	
Z top		0.0248557	
Z bottom		0.0147443	

Calculation of Xu, Section Modulus for Bottom Slab



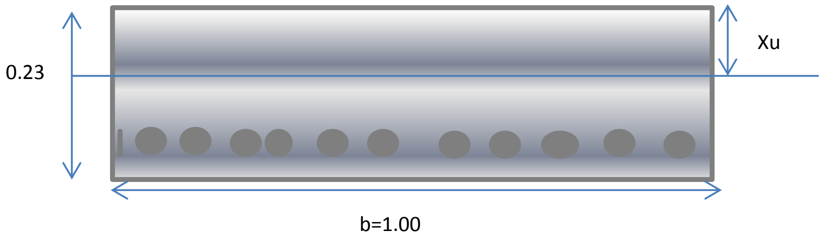
effective depth of section	0.1530
Assume neutral axis	0.0505
Modulur ratio	6.4516

Comparing moment of area(for Compression and tension) about neutral axis

B*Xu*xu/2= m*ast*(d-Xu)

Moment of area above neutral axis	0.0013	
Moment area below neutral axis	0.000586	
	Goal seek	0.000690
Crack moment of inertia of concrete	0.001286 m^4	
Moment of inertia of steel	0.000060 m^4	
Total crack moment of inertia	0.0013465	
Z top	0.0266572	
Z bottom	0.0131379	

Calculation of Xu, Section Modulus for Side wall



effective depth of section	0.1300
Assume neutral axis	0.0443
Modulur ratio	6.4516

Comparing moment of area(for Compression and tension) about neutral axis

B*Xu*xu/2= m*ast*(d-Xu)

Moment of area above neutral axis	0.0010	
Moment area below neutral axis	0.0001851	
	Goal seek	0.000797
Crack moment of inertia of concrete	0.000990 mm^4	
Moment of inertia of steel	0.000016 mm^4	
Total crack moment of inertia	0.0010056	
Z top	0.0226858	
Z bottom	0.0117383	

Stress calculations at different section

Section Mark as	**Design Bending Moment**	**Section Modulus**		**Stress**		**Check**
	t-m	**Zt**	**Zb**	**Steel**	**Concrete**	
14	2.1	0.0249	0.0147	928.51	85	ok
15	3.0	0.0249	0.0147	1317.95	121	ok
2	2.8	0.0267	0.0131	1375.49	105	ok
5	3.5	0.0267	0.0131	1718.25	131	ok
11	2.9	0.0227	0.0117	1587.31	127	ok
12	1.3	0.0227	0.0117	726.05	58	ok
12	0.0	0.0227	0.0117	0.00	0	ok
10	3.1	0.0227	0.0117	1701.08	136	ok